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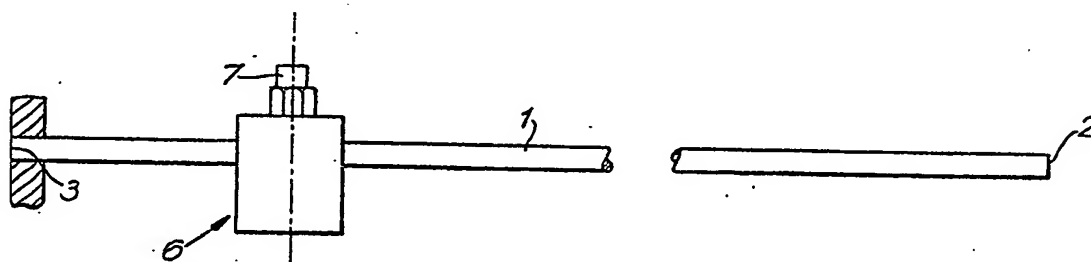(72) Inventors Stanley Hassell, Walter Mark Culling, John Carr
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(54) **Dynamic gas pressure measuring device**

(57) Dynamic pressure fluctuations are sensed remotely by means of a transducer 7 communicating through a small hole in a wall of a duct 1 formed by a length of tube closed at one end 2 and open at its other end 3 to a space in which pressure is to be measured (for example, a high temperature region in a gas turbine engine). To ensure a resonance-free aperiodic frequency response characteristic, enabling dynamic pressure variations to be detected up to frequencies of several kHz, the hole is arranged closer to the open end than the closed end and an attenuation insert in the form of a rod or tube may be located adjacent the closed end. The transducer which may include an electrical strain gauge is protected from high temperature or other hostile conditions at the sensing point.
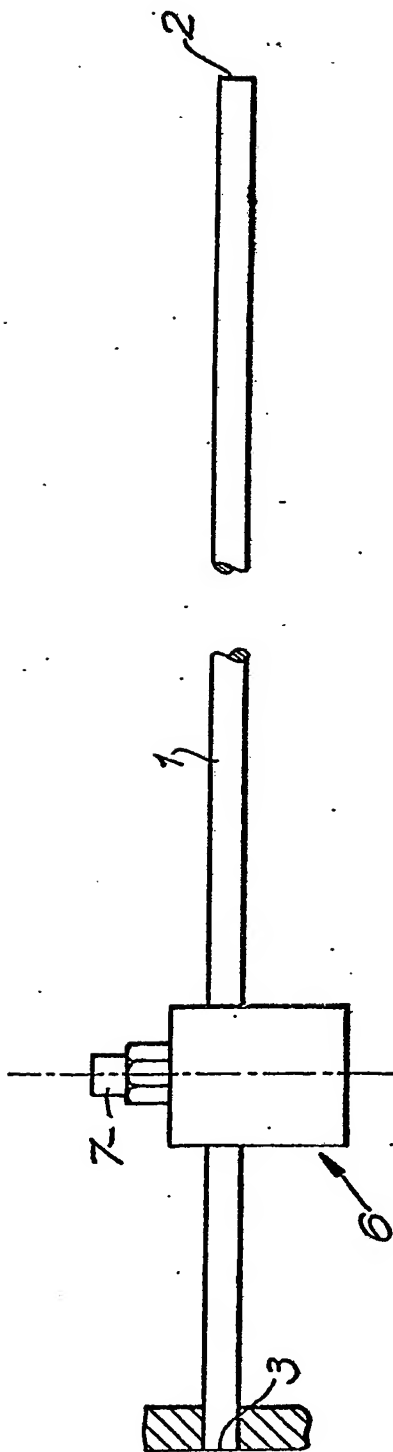
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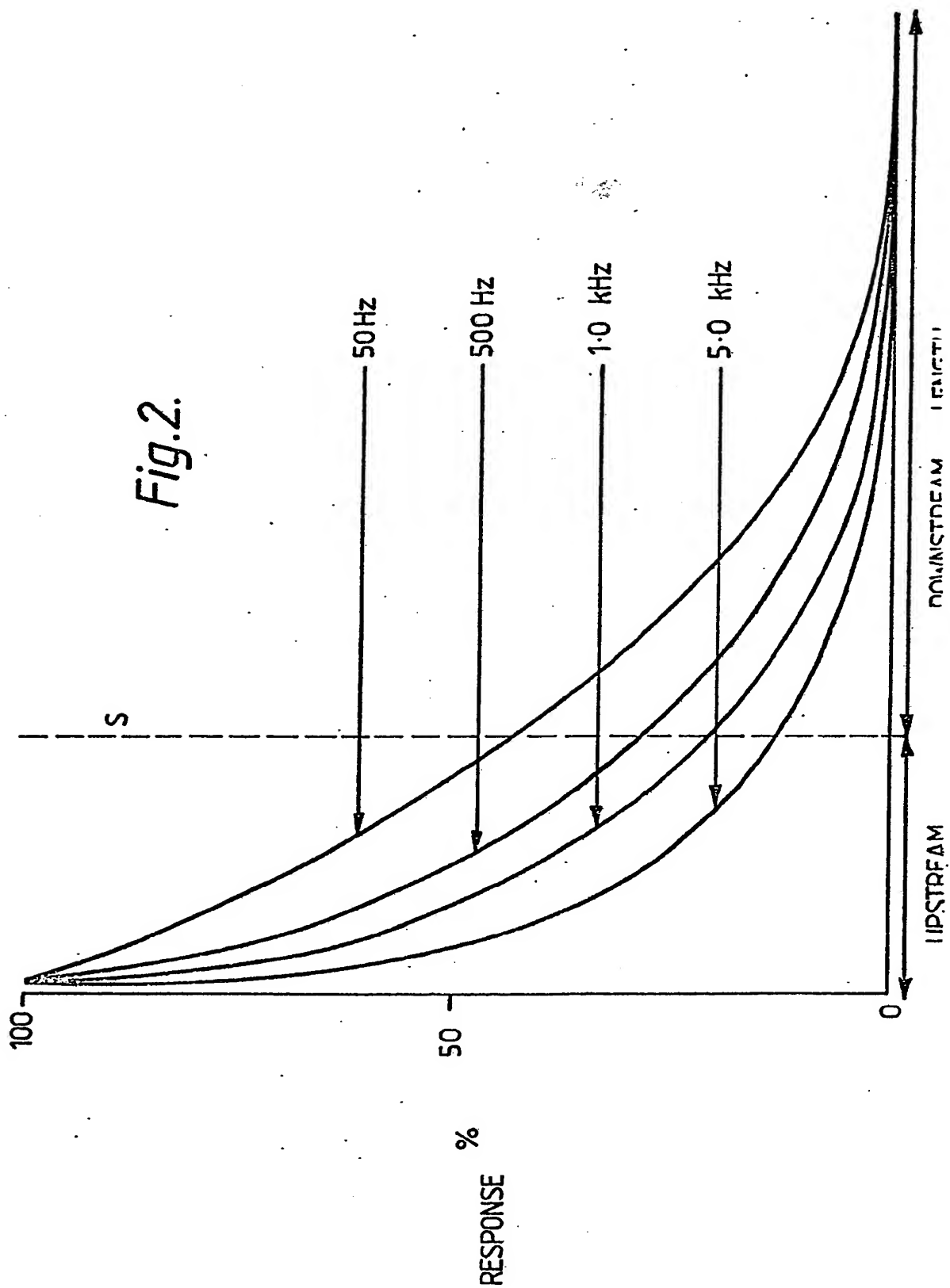
Fig.1.

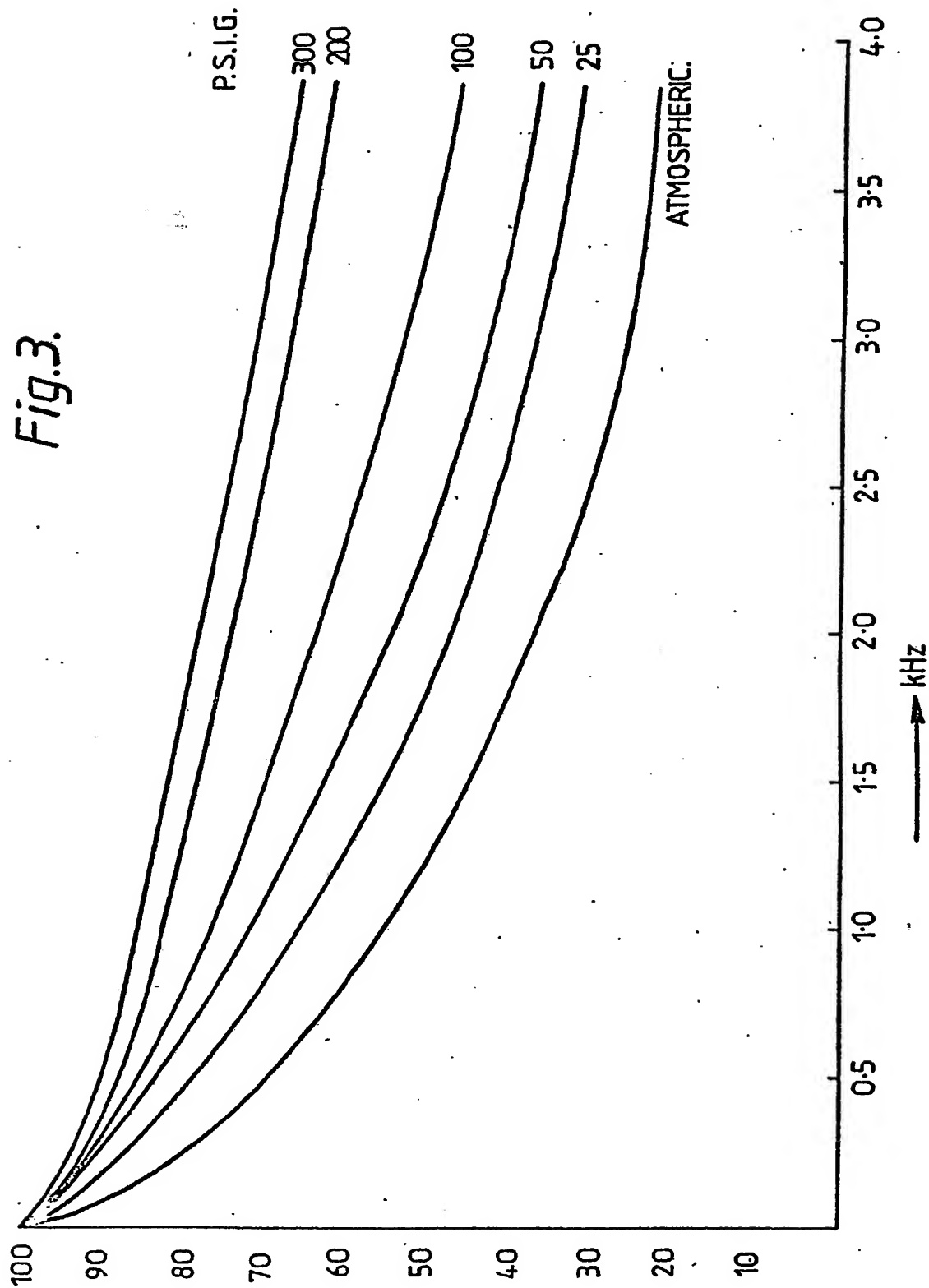
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Fig.1.

Fig.2.

Fig.3.

P.S.I.G.
300
200
100
50
25
ATMOSPHERIC.
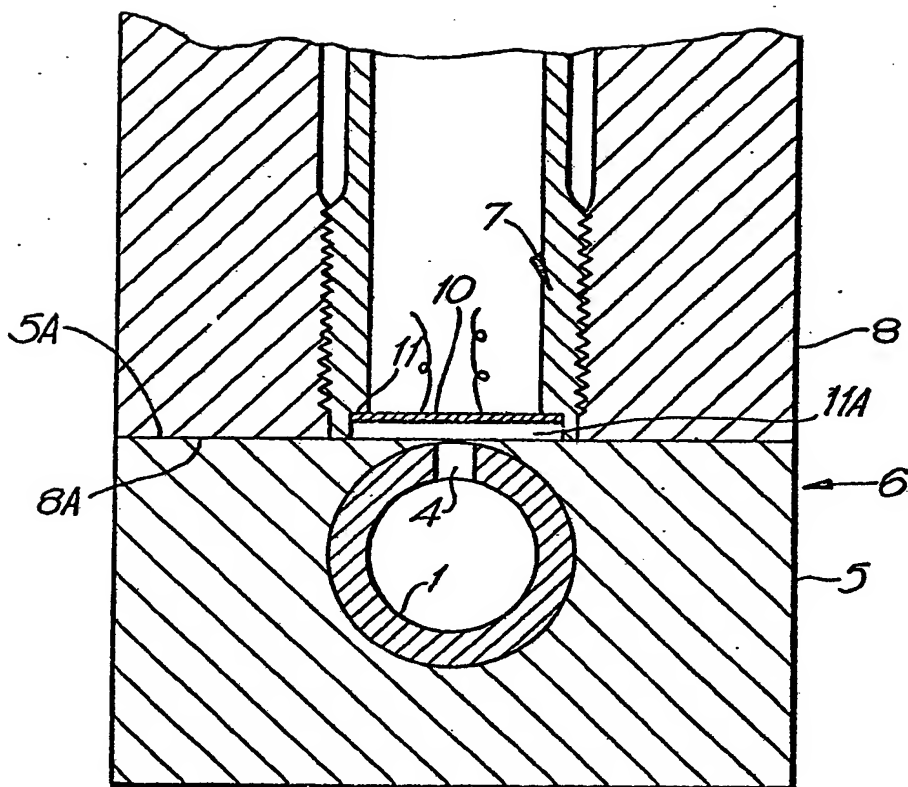
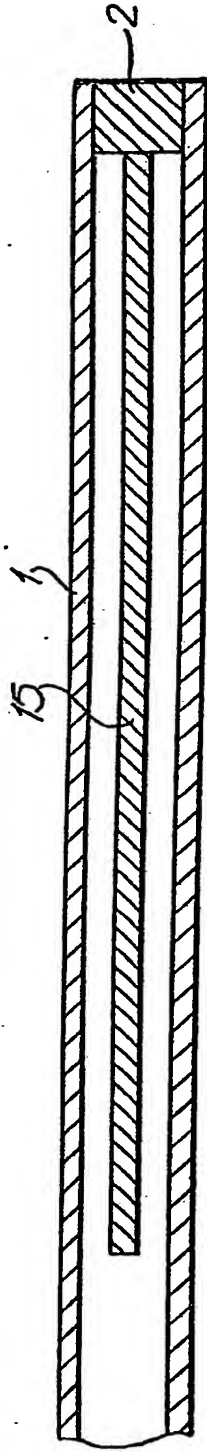← kHz

Fig.4.

Fig.5.

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Fig.6.

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Fig.7.

Fig.8.
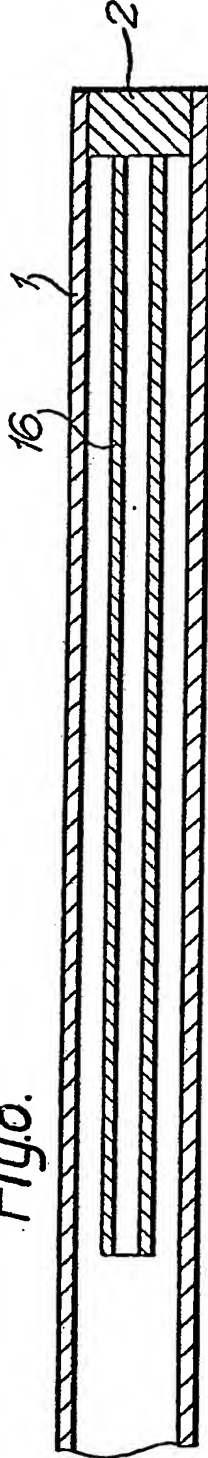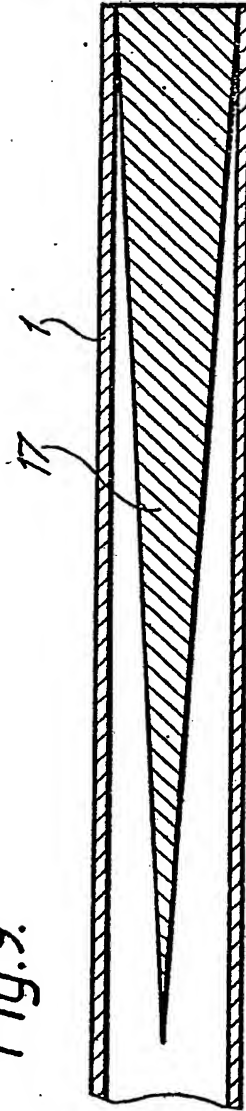
Fig.9.

SPECIFICATION
Dynamic gas pressure measuring device

This invention relates to pressure measuring
devices, particularly devices for measuring dynamic
5 pressure in a gas remotely from a pressure sensing
point.

A problem which arises in many industrial
applications is that of measuring dynamic
pressures, that is, pressure fluctuations, in regions
10 of high gas temperature and/or high static
pressure, such as occur, for example, in gas
turbine engines.

An object of the present invention is to provide
a pressure measuring device capable of measuring
15 dynamic pressure changes in a gas remotely from
a pressure sensing point, over a range of
frequency variation, and with minimal risk of
damage to the sensor as a result of high
temperatures or other hostile conditions at the
20 sensing point.

According to the invention there is provided a
pressure measuring device for measuring dynamic
pressure fluctuations in a gas remotely from a
pressure sensing point, comprising a system
25 formed by a duct closed at one end and
communicating at its other end with the pressure
sensing point, and a pressure transducer
communicating with a hole in the wall of the duct
intermediate the two ends of the duct for
30 measuring the dynamic pressure in the duct, the
system configuration, including the length of the
duct on each side of the transducer, being such
that the frequency response characteristic of the
system is free of resonances over a useful range of
35 frequencies of pressure fluctuation.

Since the duct in which the pressure
measurements are made is closed at one end
there is no steady flow of gas along the duct, and
accordingly the transducer is protected from high
40 gas temperatures at the sensing point.

Preferably the length of the duct between the
hole in the wall of the duct and the closed end of
the duct is greater than the length of the duct
between the said hole and the sensing point. It
45 can be arranged that if the duct has a sufficient
length in relation to its internal diameter dynamic
pressure fluctuations along the duct are
attenuated to substantially zero amplitude at the
sealed end of the duct, so that the duct is for
50 practical purposes equivalent to a tube of infinite
length downstream of the position at which the
transducer is mounted. This ensures a smooth
frequency response free of resonances over an
acceptable range of frequencies of pressure
55 fluctuation.

The pressure transducer preferably includes a
diaphragm mounted adjacent the hole in the duct
wall and defining a fluid-tightly sealed chamber in
communication with the said hole, and means
60 responsive to deformation of the diaphragm as a
result of the dynamic pressure to be measured to
provide an electrical output representative of said
dynamic pressure.

It is important that the hole in the duct wall at

65 which the transducer is mounted should present a
negligible discontinuity to the pressure
fluctuations in the duct. Thus the cross-sectional
area of the hole in the duct wall should be
substantially smaller than the internal cross-
70 sectional area of the duct. In one embodiment of
the invention the duct has a flattened cross-
section in the portion in which the transducer is
mounted, the transducer itself being located flush
with one of the flat inner wall surfaces of the duct.

75 The duct may in practice comprise a sufficient
length of metal or plastics tubing having a sealed
termination at the closed end. For some practical
applications it may be impractical to have an
adequately long length of uniform cross-section
80 tubing downstream of the region at which the
transducer is mounted, in which case pressure
wave attenuation means may be disposed in the
duct between the hole in the duct wall and the
closed end. Such attenuation means should, of
85 course, be essentially non-reflective. In one
embodiment of the invention the attenuation
means may comprise a length of rod or tube
inserted into the duct between the closed end and
the hole in the duct wall. Alternatively, the
90 attenuation means may be formed by a region in
which the internal air space within the duct tapers
in cross sectional area towards the closed end of
the duct. The tapered cross-sectional area may be
defined by an insert within the duct tapering in
95 cross-section from the closed end of the duct to a
point disposed between the closed end and the
hole in the duct wall.

The invention will be further described, by way
of example, with reference to the accompanying,
100 purely diagrammatic drawings, in which:

Figure 1 is a schematic illustration of a pressure
measuring device according to one embodiment
of the invention;

Figure 2 illustrates graphically a typical set of
105 dynamic pressure attenuation curves for pressure
fluctuations along the length of the duct of the
device shown in Figure 1;

Figure 3 illustrates graphically a set of
frequency response curves for dynamic pressure
110 variations at different static pressures as
measured by the transducer of the device shown
in Figure 1;

Figure 4 is a diagrammatic axial section, on an
enlarged scale, of the transducer and part of the
115 duct of the device shown in Figure 1;

Figure 5 is a diagrammatic plan view of the
transducer and portion of the duct shown in Figure
4;

Figure 6 is a cross-section taken on line VI—VI
120 in Figure 4, and

Figures 7, 8 and 9 are diagrammatic axial
sections of downstream end portions of the duct
of the device shown in Figure 1, illustrating
different forms of attenuation means adjacent the
125 closed end of the duct.

The device shown in Figure 1 is adapted for the
measurement of dynamic pressure fluctuations in
a gas at high temperature and static pressure, for
example at a point in the turbine of a gas turbine

engine. The device comprises a long pressure duct formed from a length of metal tubing 1 closed at one end by a sealed termination 2 and open at its other end 3, at which the tubing 1 is in
5   communication with a pressure sensing point at which the pressure to be measured is sampled.

The wall of the tubing 1 forming the sampling duct has a smooth internal bore and is perforated intermediately to ends of the duct by a small hole
10   4 (Figures 4 to 6) having a diameter which is significantly less than the internal diameter of the sampling duct itself, so as to constitute a negligible discontinuity as far as dynamic pressure fluctuations in the duct are concerned. Typically,
15   for a duct formed by 3 mm outside diameter tubing the hole 4 would have a diameter of 0.5 mm or less. The hole 4 is located nearer the open sampling end 3 of the tubing 1 than the closed end 2. In a typical practical embodiment the
20   length of the sampling duct upstream of the hole 4, that is, between the hole 4 and the open end of the duct, would be 0.5 metres, while the length of the tubing 1 between the hole 4 and the closed end 2 would be 18 metres for uniform cross-
25   section tubings.

The portion of the tubing 1 in which the hole 4 is formed is located in a base portion 5 (Figure 6) of a "transition block" 6 (Figure 1) in which a pressure transducer 7 is mounted. The base
30   portion 5 has a through-bore in which the tubing 1 is a gas tight fit, the hole 4 in the wall of the tubing opening into a face 5A of the base portion 5 against which a corresponding face 8A of a transducer block 8 is sealed, for example by
35   means of an O-ring located in an annular groove 9 and surrounding the hole 4 concentrically in the assembled position of the block 8 on the base portion 5.

The transducer 7 has a diaphragm 10, shown in
40   broken outline in Figure 4, which is supported peripherally against an annular lip 11 defining a small chamber 11A which communicates with the hole 4 in the wall of the tubing 1 when the transducer block 8 is assembled on the base
45   portion 5 so that the diaphragm 10 is exposed to the pressure fluctuations transmitted to it through the hole 4 from the interior of the tubing 1.

Pressure fluctuations in the tubing 1 are sampled at the hole 4 and are transmitted to the
50   diaphragm 10. The pressure fluctuations are converted into electrical signals by means of suitable transducer elements (not shown) for example strain gauges provided on the face of the diaphragm 10 opposite that which is exposed to
55   the hole 4. The electrical signals from the transducer elements associated with the diaphragm 10 are taken from the transducer 7 through leads 12, and a reference pressure is applied to the opposite face of the diaphragm 10
60   from that which is exposed to the hole 4 through a reference pressure inlet 14.

The dynamic pressure fluctuations along the length of the sampling duct formed by the tubing 1 decay approximately exponentially along the
65   length of the sampling duct, as illustrated

graphically in Figure 2, in which the position of the hole 4 at which the pressure in the duct is sampled is indicated by a line S. The attenuation of the higher frequency pressure fluctuations is
70   greater than that of the lower frequency fluctuations, but in practice this does not impair the effectiveness of the device, since the transducer 7 can have an inherently high signal/noise ratio.
75   The frequency response of the transducer located at the sampling hole 4 for different frequencies of pressure fluctuation is illustrated diagramatically in Figure 3 for different static pressures. It will be seen that the frequency
80   response is substantially aperiodic and free of resonances over a useful range of frequency variation.

In order to reduce the total length of the sampling duct downstream of the transducer 7,
85   that is, between the sampling hole 4 and the closed end 2, various types of attenuator device may be located within the downstream section of the tubing 1. Three examples of such attenuator are illustrated diagrammatically in Figures 7, 8 and
90   9. In Figure 7, a rod 15 is inserted coaxially into the downstream end of the tubing 1, from the closed end 2 of the latter, while Figure 8 illustrates a similar arrangement using a coaxial length of tubing 16 of smaller outside diameter than the
95   internal diameter of the tubing 1 itself. An alternative form of attenuator, illustrated diagrammatically in Figure 9, consists of a tapered insert 17 forming the closed end of the tubing 1 and tapering to a point between the closed end
100   and the sampling hole 4, so as to form an air passage within the tubing 1 of gradually tapering cross-section area and increasing surface area. An equivalent arrangement to this, which could also be used, would utilise an insert of cylindrical shape
105   inserted into a frusto-conical end portion of the tubing 1 tapering in diameter towards the closed end where the tubing 1 would be sealed to the surface of the insert.

In a typical practical embodiment of the device
110   according to the invention, pressure fluctuations at frequencies up to several kilohertz were measurable by means of a transducer 7 cooperating with a sampling hole 4 located as described above, the pressure fluctuations being
115   at mean pressure levels between atmospheric and 300 p.s.i.g.

CLAIMS
1. A pressure-measuring device for measuring dynamic pressure fluctuations in a gas remotely
120   from a pressure sensing point, comprising a system formed by a duct closed at one end and communicating at its other end with the pressure sensing point, and a pressure transducer communicating with a whole in the wall of the
125   duct intermediate the two ends of the duct for measuring the dynamic pressure in the duct, and system configuration, including the length of the duct on each side of the transducer, being such that the frequency response characteristic of the

system is free of resonances over a useful range of
frequencies of pressure fluctuation.

2. A device according to Claim 1, in which the
length of the duct between the hole in the wall of
5 the duct and the closed end of the duct is greater
than the length of the duct between the said hole
and the sensing point.

3. A device according to Claim 1 or Claim 2, in
which the pressure transducer includes a
10 diaphragm mounted adjacent the hole in the duct
wall and defining a fluid-tightly sealed chamber in
communication with the said hole, and means
responsive to deformation of the diaphragm as a
result of the dynamic pressure to be measured to
15 provide an electrical output representative of said
dynamic pressure.

4. A device according to any one of the
preceding claims, in which the cross-sectional
area of the hole in the duct wall is substantially
20 smaller than the internal cross-sectional area of
the duct.

5. A device according to any one of the
preceding claims, in which the duct has a flattened
cross-section in the portion in which the
25 transducer is mounted, the transducer being
located flush with one of the flat inner wall
surfaces of the duct.

6. A device according to any one of the
preceding claims, including pressure wave
30 attenuation means disposed in the duct between
the hole in the duct wall and the closed end.

7. A device according to Claim 6, in which the
attenuation means comprise a length of rod or
tube inserted into the duct between the closed
35 end and the hole in the duct wall.

8. A device according to Claim 6, in which the
attenuation means are formed by a region in
which the internal air space within the duct, tapers
in cross-sectional area towards the closed end of
40 the duct.

9. A device according to Claim 9, in which the
tapered cross-sectional area is defined by an insert
within the duct tapering in width from the closed
end of the duct to a point disposed between the
45 closed end and the hole in the duct wall.

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